International Journal of Thermal Sciences 50 (2011) 890–897

Contents lists available at ScienceDirect

International Journal of Thermal Sciences

journal homepage: www.elsevier.com/locate/ijts

Numerical computation of thermal and electrical constriction resistance in finite tube

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ARTICLE INFO

Article history:
Received 7 September 2010
Received in revised form
4 January 2011
Accepted 4 January 2011
Available online 12 February 2011

Keywords:
Constriction
Thermal resistance
Electrical resistance
Heat flux tube
Average contact temperature
Dimensionless constriction function

ABSTRACT

This study presents an analysis of the coupled electrical and thermal constriction phenomena. The finite element method is used to calculate constriction resistance (thermal and electrical) of a conducting semi-infinite cylinder subjected to heat and current spot at the same time. Three fundamental cases are presented successively. The first case deals with the transient thermal constriction in a semi-infinite heat flux tube. The second one deals with the steady state electrical constriction in the same geometry. The third and most important case presents the numerical computation of constriction resistance when the semi-infinite tube is the site of volumetric heat generation resulting from Joule effect (electrical conduction). The preliminary studies are conducted to validate the numerical computation by their comparison to available analytical solutions in the literature. The transient thermal constriction resistance and the steady state electrical constriction resistance are presented and analyzed for different constriction ratio and coupling parameter. All presented examples use a uniform spatial distribution of the electrical density and the heat flux dissipated by the spot.

1. Introduction

There are several technological applications in which heat and electricity need to cross a contact interface such as resistance spot welding, sliding electrical contact, electronic components, heat exchangers, switching devices and so on. In all of these applications, efficient heat removal is essential and the temperature field should be known precisely in order to avoid the damage of the plant in which the devices operate. If heat is transferred through a contact interface, the heat flow is constrained to flow through the sparsely spaced actual contact spots. This phenomenon is known as thermal constriction resistance.

Constriction resistance is due to the imperfect contact of two solids at their common interface. It plays a major role in heat generation and conduction in many industrial processes and its knowledge is the key in estimating thermal contact resistance or inversely thermal contact conductance. From the 1960's to today, this subject has been extensively analyzed by several researchers. Refs. [1–5] give more details on the fundamentals of thermal contact resistance and its characteristics in uncountable configurations of geometry, mechanical load, thermal environment, contact materials… Mathematically speaking, the constriction resistance is defined as the ratio of the additional temperature drop due to constriction to the rate of heat flow through the interface. A number of studies [1–12] have been carried out on the analysis of thermal constriction resistance between two solids in contact.

This contact resistance is not just aimed at the heat transfer phenomenon, the same goes for electrical conduction. Similarly this electrical contact resistance has been and remains the subject of several research works around the world. The early developments of electrical contact theory owes much to Holm: his book [13] is very well known and represents the first available reference on the subject. A series of special international conferences dedicated to this fundamental problem is held every 3 years.[1]

Most of the existing research works on the constriction resistance phenomenon were conducted assuming steady state heat conduction, and it is not clear how these would change for a transient situation. Transient spreading or constriction resistance occurs during startup and is important in many situations: electrical devices, microelectronics, sliding, metal tuning… Analytical

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[1] ICEC: International Conference on Electrical Contacts Phenomena, IEEE Holm Conference Electrical Contacts.

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doi:10.1016/j.ijthermalsci.2011.01.009